MULTIMEDIA UNIVERSITY

STUDENT ID NO

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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EOP 4076 – LASER TECHNOLOGY AND APPLICATIONS

(OPE)

1 MARCH 2019
3.00 p.m – 5.00 p.m
(2 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of **6** pages including cover page with **4** Questions only.
2. Attempt **ALL** questions. All questions carry different marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) (i) With the aid of a suitable figure, describe the term *temporal coherence length.*

[5 marks]

(ii) There are two laser sources emitting at 488 nm, wherein one laser source has a linewidth of 30 MHz, while the other laser source has a linewidth of 50 MHz. Using appropriate formulas, choose which laser source is having a longer temporal coherence length.

[6 marks]

(b) Show in detail the derivation of the mathematical model of the mode distributions at the mirrors for the TEM_{21} mode in terms of the transverse variables x, y, $\rho = \sqrt{x^2 + y^2}$, and w (scaling constant).

[8 marks]

(c) Q-switching approach can be used to build high peak power pulsed lasers. Explain the process of *Q-switching*, and illustrate the evolution of a Q-switched laser pulse, showing the loss, gain and laser output on the same graph.

[8 marks]

(d) A mixture of Helium (He) in Hydrogen (H) will affect the transition probability by a factor of 10^7 $s^{-1}Torr^{-1}$. The average value of the transition probability, A_{ul} for the upper laser state to lower laser state of H is 4.7×10^8 s^{-1}. Evaluate the change of lifetime, τ_u of the upper laser state of H when 10 Torr of He gas is added to an electrical discharge composed of H atoms.

[6 marks]

Continued...

Question 2

(a) The excited excimer molecules are the species in the upper laser level that generates the laser emission. Explain in detail, the formation processes of these laser species in an ArF excimer laser.

[6 marks]

(b) Mode-locking approach is used to produce ultra-fast laser pulses. Design and draw an intra-cavity mask aperture in a Titanium Sapphire laser for achieving mode-locking, and explain its working principle.

[8 marks]

(c) The two host materials most commonly used for Neodymium (Nd) laser ion are Yttrium Aluminum Garnate (YAG) and glass. The drawback of Nd:glass laser materials is their relatively poor thermal conductivity. Evaluate the consequences of having poor thermal conductivity.

[6 marks]

(d) The carbon dioxide laser is one of the most powerful and efficient lasers available. This laser operates at high total gas pressures. Discuss why it is possible to operate it efficiently at high gas pressures, and explain the benefits.

[6 marks]

(e) The requirements for population inversion for an Argon ion laser that operates as a three-level when considering only the single-ion energy levels is given by,

$$\left(\frac{g_l}{g_u}\right)\frac{1}{\left(1+\Gamma_{0l}/\Gamma_{0u}\right)}\frac{A_{l0}}{A_{ul}} > 1$$

where $g_l = 4$ and $g_u = 6$ are the statistical weights of levels u and l, Γ represents the external applied pumping process and A represents the normal radiative decay, with the subscripts "u", "l", and "0" denote the upper laser level, lower laser level, and ground level, respectively. The transition probability, A_{ul} for the upper laser state $3p^4 4p$ is $7.8\times10^7 s^{-1}$, and the transition probability, A_{l0} for the lower laser state $3p^4 4s$ are $23\times10^8 s^{-1}$ and $4.5\times10^8 s^{-1}$. Evaluate the maximum ratio of excitation from the ground state to the lower laser level, when compared to the excitation from the ground state to the upper laser level at threshold.

[7 marks]

Continued...

Question 3

(a) Discuss the importance of using a laser with suitable wavelength when performing welding of metallic materials in micro-circuitry.

[5 marks]

(b) In a material cutting procedure, the aim is to vaporize the material as quickly as possible with minimum distortion of the workpiece. Define the terms *kerf* and *HAZ* and explain the benefit of using laser for material cutting in terms of *HAZ*.

[5 marks]

(c) One crucial operation of a factory involves cutting pure iron sheet of thickness 3.1 mm. The pure iron used has specific heat capacity $C = 460\ \text{Jkg}^{-1}\text{K}^{-1}$, latent heat of vaporization $L_v = 5.7 \times 10^6\ \text{Jkg}^{-1}$, density $\rho = 6800\ \text{kgm}^{-3}$, boiling point $T_v = 2760$ K (or 2487°C), and negligible surface reflectance R_s. A vendor is offering a laser cutting product to the factory, whereby its laser beam has a power of 0.85 kW, a beam diameter of 0.22 mm, and the scanning velocity of the laser beam v_b of 36 mm/s. As a professional consultant, you are requested to assess the laser cutting system through proper calculations to advise whether it is able to fulfil the factory operation or not.

[7 marks]

Continued...

Question 4

(a) (i) Describe the working principle of particle size distribution measurement based on laser.

[4 marks]

(ii) Explain the limitation on the measurable particle size.

[2 marks]

(b) (i) "Lock-in" problem always exists in ring laser gyroscopes. Present a detailed description (with the aid of a suitable graph) on this problem, and the conceptual solution to resolve it.

[6 marks]

(ii) An equilateral triangular ring laser gyroscope measures beating frequency of 10 Hz when the ring laser is rotated about its centre axis which is perpendicular to its ring plane at a rate of 30° per hour. If it has a laser wavelength of 632.8 nm, determine the lateral dimension of the ring laser.

[5 marks]

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Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

End of paper